Analysis on the capacity building for mitigating volcanic hazards versus the 2010 eruption of Mount Merapi, Central Java, Indonesia

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Abastract

Mount Merapi that is one of the most active volcanoes on the world had erupted again during Oktober-November 2010. Its climax activities happened on 5th November at 00.50 pm, with different eruption type from Merapi of last 50 years. Ordinary, Merapi activity initiates with lava dome development, following by dome collapse to create pyroclastic flow. This specific eruption character is called Merapi Type. But it was not displayed in the 2010 eruption period that expressed Vulcanian and Pelean type. The pyroclastic flows of 2010 killed 341 people and buried many villages on the southern slope, while the secondary hazard of lahar destroyed many other human settlements and infrastructures on the western slope of the volcano.

Actually, capacity building program in the areas around Mount Merapi has been done and established since more than 15 years ago. In most villages, there are community associations that well trained on volcanic hazard mitigation and early warning system. The association name is *Paguyuban Sabuk Gunung (Association of Mountains Belt) Merapi*. Map of merapi hazards based on the last data was also already set by the Center of Volcanology and Geologic Disaster Mitigation. But unfortunately, human are not able to order the nature. The character of Merapi 2010 eruption was inconsistent. There was much higher gas pressure, much longer pyroclastic flow distant, and much greater volcanic material poured from the crater, making people and stake holders very astonished and face an emergency in evacuation. However, a socio-cultural factor in this respect is that the local people and agriculturists view Merapi as a God which gives them fertile soil and water for agriculture and are reluctant to move away even under an impending threat of a volcanic hazard. This mind-set of people is a challenge in capacity building as the people prefer in-situ protective measures rather than moving away.

Introduction

The study area is around Mount Merapi, the volcano of which located within densely populated the territory of Central Java Province and Yogyakarta Special Province (Fig. 1). As it is known, Mount Merapi belongs to the most active volcano of Indonesia, and one of the most attractive volcanoes for volcanologists on the world. Once in every about 4 years its activity increases, threatening surrounding environment with its phenomenal *nuee ardentes*, glowing clouds, and lahar. In the year 2006, Mount Merapi showed its force, and erupted on 14 June, burying a tourist object at Kaliadem of Cangkringan District, Sleman Regency. More tremendous than that, in October to November 2010 Merapi was active again with different characteristic of eruption, killing many people and wiping out numerous villages of Cangkringan District, Kemalang District, and Magelang Regency. Although the volcano is some time

dangerous, it eternally brings blessings to the surrounding area by supplying sands, stones, fertile land, and beautiful scenery.

This paper reports and analyzes the characteristics of 2010 Merapi eruption, its impact to surrounding, and the capacity building of local communities for mitigating the volcanic hazards. Methods applied in this study were field surveying, mapping, and primary or secondary data analysis.

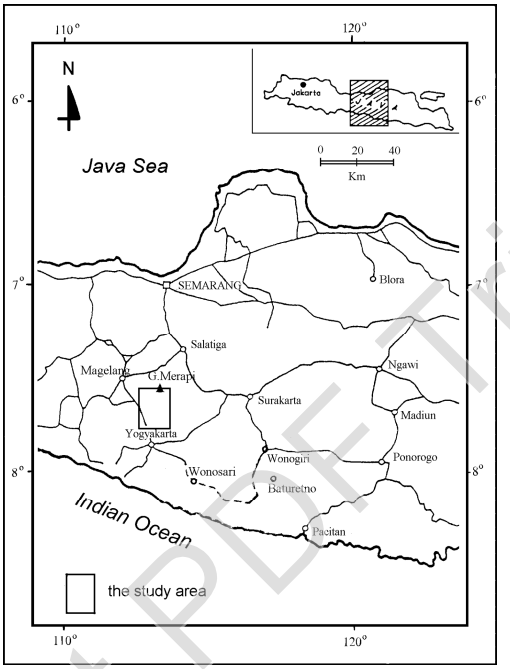

Fig. 1 Map showing the location of the study area

Merapi the Active Volcano

Mount Merapi is classified into a very active and very young volcano. Berthomier (1990) and Camus et al (2000) infer the earliest growth of the volcano began at least 40,000 years B.P. (Newhall et al, 2000). Historical records verify that the character of Mount Merapi eruption is dynamic and changed by time. Variation of effusive and explosive types have occurred, shown by diverse volcanic products such as thick lava deposits, volcanic sand, ash and dust deposits, pyroclastic breccias, and auto breccias (Kusumayudha 2001, 2008).

Mount Merapi stands on the intersection of two volcanoc lineaments, i.e. Ungaran - Telomoyo - Merbabu - Merapi and Lawu - Merapi - Sumbing - Sundoro - Slamet. Merapi also lays on the meeting point of Semarang fault (North – South) and Solo fault (West – east) (Kusumayudha 1988, vide Kusumayudha 2008). The volcano exists due to the subduction of

Indo-Australia oceanic plate to Eurasia continental plate. Partial melting beneath 75 to 125 km depth brings about calc-alkaline magma, as the source of Merapi products. Based on geophysical investigation, it is identified that the magma chamber of Merapi is relatively shallow (about 3 km bellow the ground surface), the magma is very viscous, and its gas pressure is relatively low. This condition makes Merapi activity just displaying weak explosion, lava dome development, and *nue ardentes d'avalanche* (Kusumadinata, 1979).

According to Camus et al (2000), there were four periods of Merapi volcanic activities, they are Ancient Merapi period, Middle Merapi period, Recent Merapi period, and Modern Merapi period. Ancient Merapi period is characterized by thick olivine andesite lava. Middle Merapi period produced andesitic thick lava flows and *nuee ardentes* deposits. Recent Merapi are predominantly composed of thinner lava flows, pyroclastics and epiclastic deposits, while Modern Merapi period is apecified by its "Merapi type activity", i.e. a continuous growth of summit dome interrupted by collapses and phases of quiescence (Camus et al, 2000). Below is the geologic map of Mount Merapi after 2010 eription (Paripurno, 2011)

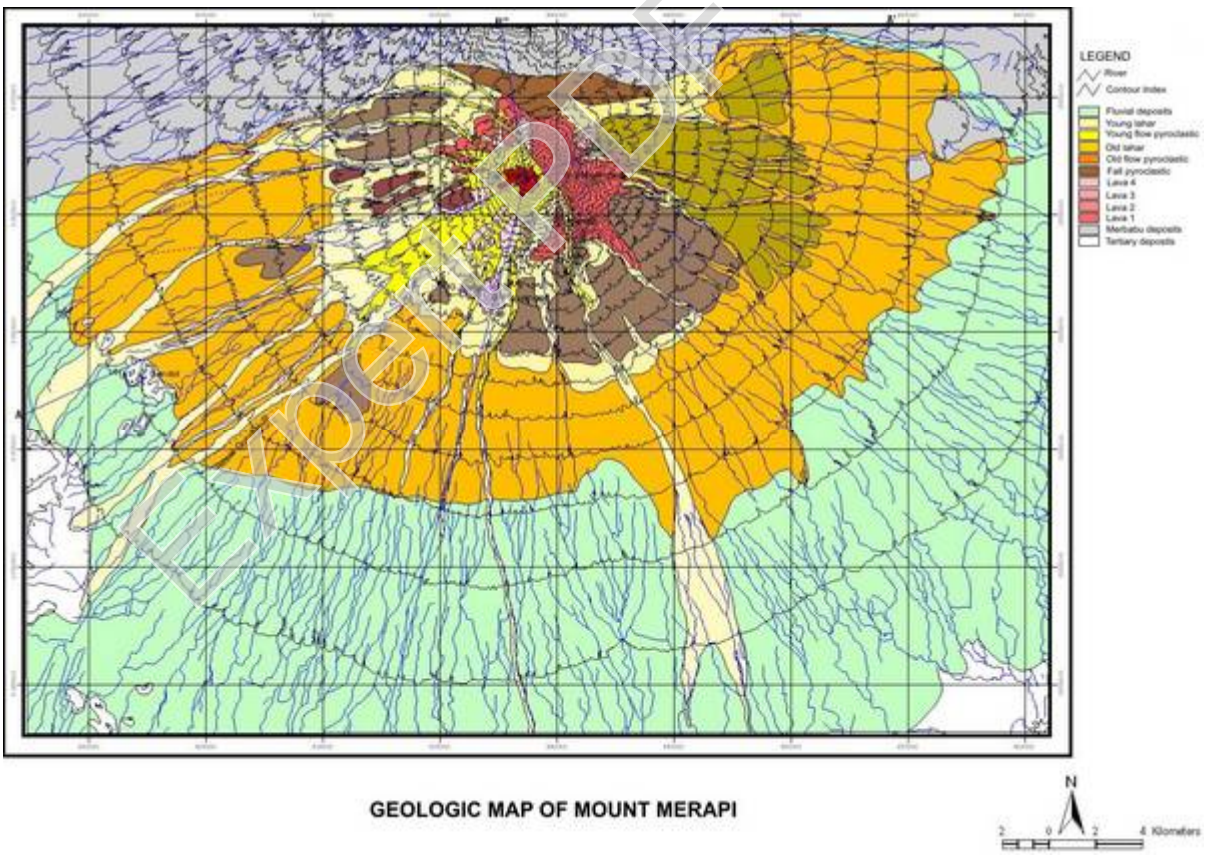

Fig. 2 The geologic map of Mount Merapi (Paripurno, 2011)

2010 Eruption

Merapi eruption of 2010 was not similar to that happened of last 50 years. Activities of which was initially start from lava dome development on the summit was not occurred this period. This time the dynamic and movement of the magma was too fast. According to BPPTK (Institute of Research and Development of Volcanic Technology), the energy of Merapi 2010 eruption was many times higher than that of 2006 eruption. In the year 2010, since the activity level was pointed to be updated from normal active to be first alert, second alert, and third alert, there was no glowing lava flows or dome detected on the summit of Merapi. But suddenly it erupted and exploded with high gas pressure on 26 October 2010.

Merapi 2010 eruption happened, while everyone was not well prepared yet. The eruption this time was more explosive, high gas pressure, and tremendous *nuee ardentes* (Fig. 3). The climax eruption occurred on 5 November early morning. According to BNPB, 2010 (http://www.bnpb.go.id/irw/berita. asp?id=247), and Kompas (2012), 341 people died, 366 injuried, 50,272 evacuated, and 3,307 buildings destroyed (Table 1). The lost was estimated approximately 4,230 billion rupiahs, including agricultures.

Merapi 2010 eruption can be classified into Vulcanian type with more than 5 km high rise dark smokes. Besides upward explosion, the eruptions were also combined with *nue ardentes d'avalanche* as ever happened to Mount St Helena, or Pelean type. The greatest pyroclastic flows occurred on 5 November early morning, reaching 15 km distant from the eruption center to southeast and south direction through River Gendol valley (Fig. 4). This eruption swept and buried many villages, such as Umbulharjo, Kepuharjo, Glagaharjo, Wukirsari, and Argomulyo (Sleman Regency) and Balerante (Klaten Regency), even Borobudur, the biggest Buddist temple that situated about 35 km from Mount Merapi was covered by volcanic ash (Fig. 5). Figure 6 and Figure 7 show the situation of post Merapi erption at some villages.

Merapi hazards were then followed by the secondary threats of lahar, because it happened in the rainy season. There were 100 million m3 (BPPTK vide Kompas, 2012) volcanic materials deposited on the upper parts of the volcano. In the River Gendol valley the thickness of pyroclastic flow deposits reach 10 m. When the deposits are to become denser by rain water and flowed down lead by gravity, lahar will occur. Since Merapi activity started, some villages along River Code (Yogyakarta), River Putih, and River Pabelan (Magelang Regency) were disturbed by lahar (Fig. 8). Impact of Merapi 2010 activity to the environment is broken down in Table 1.

Table 1 Impact of Merapi eruption 2010 (http://www.bnpb.go.id/irw/berita.asp?id=247)

Name of Regency	Province	Number of Victims			Volcanic Process Destroyer
		Died	Injuried	Evacuated	
Sleman	Yogyakarta	243	203	26,774	Pyroclastic flows
Klaten	Central Java	36	30	4,321	Pyroclastic flows
Magelang	Central Java	52	96	18,505	Lahar Volcanic ash
Boyolali	Central Java	10	37	672	Volcanic ash
Total		341	336	50,272	

Fig. 3 Merapi eruption, 10 November 2010


Fig. 4 Pyroclastic flow deposits of Merapi 5 November 2010 eruption at River Gendol.

Fig. 5 Borobudur temple that located about 35 km western of Merapi was coated by ash

Fig. 6 Situation at Kalitengah village post Merapi 2010 volcanism

Fig. 7 Ruins in Kinahrejo village after Merapi 2010 eruptions

Fig. 8 Lahar of River Putih that has broken Yogyakarta – Magelang transportation line

Disaster Community Based management

Disaster management in general has been well understood and run by most Indonesian people (Government, NGO, academician, and community), especially who live in the vulnerable area of earthquake, landslide, and active volcano. Theoretically, disaster management can be run by steps of activities, i.e. pre disaster, sin disaster, and post disaster.

In Yogyakarta Special Province, especially for areas which are often impacted by Merapi eruption, the government stated procedures of disaster management activity steps as the following (Paripurno et al, 2011):

1. **Research:** It is done to study the phenomenon and characteristics of Merapi activities, especially in the area frequently affected by Merapi eruption. Culture of the local people including local wisdoms is important to be studied and understood.
2. **Vulnerability Analysis and Risk Assessment**: There are several threats of Merapi volcanic activity, i.e. *nee ardentes* (glowing cloud), volcanic ash and dust, and secondary hazard of lahar. Matrix of these threat variables and their risk should be assessed, how one variable, combination of two or several variables would be.
3. **Socialization and Community Preparedness:** Local people or community member are touched on natural phenomenon and anticipative action. This has been done by local and province Government, represented by BPPTK in collaboration with NGO and universities in Yogyakarta.
4. **Mitigation:** This is the preparedness to facing disaster occurrence or alert situation. Preparation to facing Merapi hazards includes providing evacuation lines, disaster centers, evacuation barracks, and logistic. On the other hand, monitoring of Merapi activities will be done intensively by BPPTK, and the results will always be communicated and informed to the local Government, local community leaders, and related NGO.
5. ***Warning System*:** When Merapi situation is already in the second alert level, socialization regarding the possibility of big eruption should be communicated as soon as possible, not only by persuasive effort, but also powered effort. Early warning can be disseminated by lectures in schools or meetings, sermon at churches or mosques, siren, or SMS blast to every cellular phone owners.
6. **Saving:** When glowing cloud occurs, the safest method to avoid the risk is escape from the vulnerable area to places or evacuation barracks with suitable logistic.
7. **Communication:** Communication is important, and can be done by using satellite telephone system. It is in order for the hazard can be detected as early as possible from Yogyakarta as the capital city of the province, and Jakarta as the capital city of the country.
8. **Emergency Handling:** When there is someone injured or need to be medically treated, or even missing, the preparedness of the SAR team must be well organized and coordinated.
9. **Management Sustainability:** If Merapi activity is not subsided in a short time, the mitigation process will need to be handled continuously. Well coordination, collaboration must be set up involving local Government, province Government, central Government, and all stakeholders.
10. **Restoration:** This activity belongs to post disaster step, including the healing process that may consume such a long time. Renovation planning need to be done carefully because

the cost may be high. The cost can be supported by various communities either from local, regional, National, even international.

11. **Training and Education:** To achieve the best disaster management results, in every vulnerable area should be some skilled and trained officers. Therefore next education and training will be able to be held for other officers, community members, and NGO members.
12. **Simulation:** After the volunteers are ready, every vulnerable area should hold simulation on disaster handling process in order all the community members and their family able to anticipate and save their selves from disaster threats.

Mitigation and Capacity building

Mitigation action as a part of disaster management is actually already done when Merapi active in 2010. In that time, based on the result of monitoring done by BPPTK Yogyakarta, the activity status had been updated to be third alert on 24 October morning, at 06.00 am local time. By this status, all people were reminded that Merapi possibly erupt any time. Some works had been done including seismicity and geochemical analyses on gas and rock samples, and ground deformation observation using EDM (*Electronic Distance Measurement*). The monitoring were completed with visual observation to identify lava dome development, lava dome avalanche, and solfatar emission intensiveness. This informs us that such comprehensive approaches had been well done in order to affirm the activity status of Merapi.

On behalf of the status change of Merapi since 24 October 2010, people were suggested with self awareness to leave their places quickly. In that time, old people, women, and children were the first priority to be evacuated. But unfortunately, next day, some people had been evacuated came back to their village for daily activities.

Some evacuated people came back to their places, because after they stay in the barrack, in fact Merapi did not erupt. On the other hand, they think that they already had the experiences on facing Merapi eruption. They believed that Merapi would take long enough time for preparing it eruption, because there were no natural signals yet, such as eagles flying around the sky, wild animals (tiger, monkey) going down the mountain, thundering sound from Merapi “stomach”, etc. Furthermore, at that time the volcano keeper, mbah Maridjan enstated that he did not yet get any signs and feelings that Merapi would erupt.

Merapi 2010 eruption period was a very valuable lesson for all stakeholders. Disaster management have already run, but still there were hundreds people killed. In the future well coordination, well preparation, and well communication among all stakeholders and especially local people must be well done. Local people should be submissive to Government and official

instruction especially when they have to be evacuated. This is in order to minimize the number of victims and risk as minimal as possible.

In principle, capacity building is intended to reduce the vulnerabilities, either as stand-alone disaster preparedness and mitigation measures, or as an integrative process. In contrary, communities will be weak to face the threats with lack or limited capacity to reduce the risks. Generally, disaster risk reduction capacity of officers, community members, and civil society groups will be able to well built and strengthen, either integrative or separately, through frequent communication, discussion, workshop, trainings, education, and socialization, without discarding the local wisdoms. In every village located around Merapi, there are community associations, called *Paguyuban Sabuk Gunung (Association of Mountains Belt),* that well trained on volcanic disaster mitigation and early warning system.

Related to Merapi 2010 lessons, capacity building actions by communities and local government are set up in various levels. In the government level, is done by planning disaster risk reduction (DRR) program, the program is then advocated to the lower level, in order to be run by the communities. The communities establish their DRR action plan for example by setting Village Preparedness Team and other activities in their places. Government and local communities are linked through joint activities such as contingency planning, drills, monitoring and evaluation. The program has been running since the last two years, showing positive growth condition (Paripurno et al, 2011). To achieve better result of capacity building, good collaboration and cooperation of local government, communities, and all stakeholders are needed through some ways such as discussions, workshops, and trainings.

Conclusion

1. Mount Merapi erupted during Oktober-November 2010; The climax eruption was on 5th November at 00.10 am;
2. Previously, the character of eruption was Merapi type, but this time it changed to be Vulcanian and Pelean type, with much higher gas pressure, much longer pyroclastic flow distance, and much greater volume of material.
3. The pyroclastic flows of 2010 reached 15 km distant from the center of eruption, killing 341 people, injuring 366 and destroying 3,307 buildings. The lost was estimated approximately 4,230 billion rupiahs, including agricultures.
4. Capacity building program has been done and established since more than 15 years ago. In most villages, there are well trained community associations, called *Paguyuban Sabuk Gunung (Association of Mountains Belt).* Map of merapi hazards was also provided

5. During Merapi 2010 eruption, the mitigation was constrained by a socio-cultural factor; People were reluctant to be evacuated due to the change of Merapi eruption character that was "undetected" by local wisdom
6. Local people view Merapi as "a God" who gives them everything for life.

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